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September 21, 1998

Mr. William F. Caton
Secretary
Federal Communications Commission
Room 222
1919 M Street, N.W.
Washington, D.C. 20554

Re: WT Docket No. 98-136

In the Matter of Amendment of
Part 27 of the Commission's Rules to
Revise Rules for Services in the 2.3 GHz
Band and to Include Licensing of
Services In the 47 GHz Band

Dear Mr. Caton:

Transmitted herewith by the National Academy of Sciences, through the Committee on Radio Frequencies of the National Research Council, are an original and 9 copies of its Comments in the above-referenced proceedings.

If additional information is required concerning this matter, please communicate with this office.

Sincerely yours,

Robert L. Riemer

Robert L. Riemer
Senior Program Officer

Enclosure

cc: Members of CORF
Mr. Paul J. Feldman
Dr. Tomas Gergely
Dr. Donald C. Shapero

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In the Matter of Amendment of Part 27 of the Commission's Rules to Revise Rules for Services in the 2.3 GHz Band and to Include Licensing of Services in the 47 GHz Band	))))))))	WT Docket No. 98-136

COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, "CORF"; the membership is listed in Appendix A), hereby submits its Comments in response to the Commission's July 29, 1998, Notice of Proposed Rulemaking in the above-captioned docket ("NPRM"). In these Comments, CORF suggests that the Commission forbear from enacting rules on out-of-band and spurious emission limits on high-altitude-platform users of the 47 GHz band until related matters are properly resolved on an international basis. Until such time, aeronautical and space-borne uses of the 47 GHz band should not be authorized. However, if the Commission decides to enact interference limits prior to international resolution, the limits must be significantly more stringent than those proposed in the NPRM, in order to protect Radio Astronomy Service ("RAS") observations in nearby bands from harmful interference.

I. Introduction: The Importance of Radio Astronomy Observations in the 42.5-43.5 and 48.94-49.04 GHz Bands, and the Unique Vulnerability of Radio Astronomy to Out-of-Band and Spurious Emissions.

CORF represents the interests of the radio astronomy community, as well as that of other scientific users of the radio spectrum, and therefore has a substantial interest in this proceeding. As the Commission has long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. Through the use of radio astronomy, scientists have recently discovered the first planets outside the solar system, circling a distant pulsar. Measurements of radio spectral line emission have identified and characterized the birth sites of stars in our own Galaxy, and the complex distribution and evolution of galaxies in the universe. Radio astronomy measurements have discovered ripples in the cosmic microwave background, generated in the early universe, which later formed the stars and galaxies we know today. Observations of supernovas witness the creation and distribution of heavy elements essential to the formation of planets like the Earth, and of life itself. In addition to increasing knowledge of the universe, radio astronomy has produced substantial benefits through the development of very-low-noise receivers and many other applications used in a variety of radio applications. The technique of very-long-baseline interferometry ("VLBI"), developed for high-resolution radio astronomy, is used by geophysicists to study small motions of the Earth's crust. These terrestrial observations include identification of potential earthquake zones through measurement of fault motion. VLBI techniques also make major contributions to accurate navigation, including the tracking of spacecraft. The benefits of radio astronomy have been obtained through years of work and a large federal investment. They and future benefits must be protected.

As passive users of the spectrum, radio astronomers have no control over the frequencies that they need to study or over the character of the signals from cosmic objects. These parameters are set by the laws of nature. Furthermore, the emissions that radio astronomers receive are extremely weak--a radio telescope receives only about one-billionth of one-billionth of a watt (10^{-18} W) from a typical cosmic object. Because radio astronomy receivers are designed to detect such remarkably weak signals, they are therefore particularly vulnerable to interference from spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and from those that produce harmonic emissions that fall within RAS bands.

Of particular concern in this proceeding is interference to radio astronomy observations in the 42.5-43.5 GHz and 48.94-49.04 GHz bands from stratospheric platforms, or other airborne or space-borne users operating in the 47 GHz band. The 42.5-

43.5 GHz and 48.94-49.04 GHz bands are allocated on a primary basis to the RAS.[1] Similarly, the International Telecommunication Union Radiocommunication Sector ("ITU-R") Recommendation RA.314-8 specifically lists spectral line observations of silicon monoxide (at 42.82 GHz and 43.12 GHz) and carbon monosulphide (at 48.991 GHz) as among the lines of greatest importance to radio astronomy.[2] Spectral-line observations of silicon monoxide are important because of the presence of that molecule in interstellar molecular clouds, in the atmospheres of evolved stars, and in external galaxies. These two lines have been observed as prominent narrow-band "maser" emission in the atmospheres of hundreds of evolved stars and star-forming regions, and are essential for studies of cosmic phenomena such as the birth and death of stars. The carbon monosulphide ("CS") molecule is a good high-density tracer, and observation of the CS spectral line is an important tool for analyzing the molecular material in active nuclei and starburst galaxies.

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[1]Observations in these bands are made at radio astronomy observatories in Goldstone, California; Green Bank, West Virginia (under construction); Socorro, New Mexico; St. Croix, Virgin Islands; Hancock, New Hampshire; North Liberty, Iowa; Fort Davis, Texas; Los Alamos, New Mexico; Pie Town, New Mexico; Kitt Peak, Arizona; Owens Valley, California; Brewster, Washington; Mauna Kea, Hawaii; Amherst, Massachusetts; Hat Creek, California; Westford, Massachusetts; and numerous other observatories in other countries.

The 42.5-43.5 GHz band is also used for sensitive continuum emission observations. To achieve the highest sensitivity in continuum observations, astronomers must use the maximum observing bandwidth available. This band is important to radio astronomy because, owing to its 1 GHz width and its location in the spectrum (at approximately twice the frequency of the 23.6-24 GHz continuum band), it provides an effective point for the sampling of continuum emission at octave or better frequency intervals. Such observations provide critical information on the physical state of the interstellar medium associated with star-forming regions.

In sum, radio astronomy observations in the 42.5-43.5 and 48.94-49.04 GHz bands are important, yet like all radio astronomy observations, are uniquely vulnerable to interference from out-of-band and spurious emissions.

II. The Commission Should Forbear from Enacting Spurious and Out-of-Band Emission Limits, and from Authorizing Aeronautical and Spaceborne Uses of the 47 GHz Band, Until Resolution at WRC-00 of Interference Standards in That Band.

The 1997 World Radiocommunication Conference (WRC-97) designated certain portions of the 47 GHz band for use by high-altitude platforms ("HAP") operating in the fixed service. However, WRC-97 Resolution 122 specifically noted that "technical studies are required in order to ascertain the

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[2]ITU-R Recommendation RA.314-8, "Preferred Frequency Bands for

extent to which sharing [of the 47 GHz band] is feasible between [HAPs and other services] and to ascertain the requirements to protect radio astronomy services in the adjacent bands from spurious emissions...." Accordingly, that Resolution requests the ITU-R to urgently carry out studies "on the appropriate technical sharing criteria" for users of the band and the RAS, with a view toward further action by WRC-99 (now WRC-00). ITU-R Joint Rapporteur Group 7D-9D was assigned this important investigatory task.

In light of the issues pending before the ITU that may directly affect the interference limits upon which the Commission is seeking Comments in paragraph 131 of the NPRM, CORF recommends that the Commission forbear from setting interference standards that could be rendered irrelevant by ITU action.

The above recommendation for forbearance does not mean, however, that airborne or space-borne users operating in the 47 GHz band should be authorized by the Commission without any limits on out-of-band or spurious transmissions. Such a result would be the worst of all possible worlds for the RAS community, as well as for other users of neighboring bands. Rather, the Commission should forbear from authorizing airborne

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Radioastronomical Measurements."

or space-borne users until interference limits are established at WRC-00.

III. If the Commission Enacts Spurious and Out-of-Band Limits at This Time, Stringent Limits Are Required in Order to Protect Important Radio Astronomy Observations in the 42.5-43.5 GHz and 48.94-49.04 GHz Bands

CORF recognizes that the Commission may conclude that, regardless of the argument made in Section II above, for other reasons, airborne or space-borne use of the 47 GHz band should be authorized prior to WRC-00. In such a case, it would be best for all parties to have spurious or out-of-band limits in place prior to construction of HAPs and other facilities transmitting in the 47 GHz band. Enactment of such limits after construction of HAPs could lead to the unfortunate situation of a fait accompli being presented to the Commission in the form of HAPs that do not meet Commission interference limit standards, but for which it is allegedly "too late" or too expensive to change production, or technically infeasible to modify equipment that has already been launched into the stratosphere.

The Commission proposes that licensees in the 47 GHz band must attenuate the power below the transmitter power (P) by at least 43 + 10 $\log_{10}(P)$ or 80 decibels, whichever is less, for any emission on frequencies outside the licensee's authorized channel. As shown in the technical portions of Appendix B, attached hereto, the emission limits proposed in the NPRM will result in harmful interference to the Radio Astronomy Service observations in the 48.94-49.04 and 42.5-43.5 GHz bands. Appendix B considers the effect of a HAP operating over the Albuquerque, New Mexico, area on the National Radio Astronomy Observatory's Very Large Array (NRAO/VLA), which is located near Socorro, New Mexico, and operates in the above radio astronomy bands. The interference produced by the HAP would exceed by nearly 40 dB the harmful interference levels given in ITU-R Recommendation RA.769-1 on "Protection Criteria Used for Radioastronomical Measurements". Accordingly, CORF proposes that the requirements for out-of-band emissions in the bands 42.5-43.5 GHz and 48.94-49.04 GHz be specifically set to the more stringent levels consistent with Recommendation ITU-R RA.769-1 (see Appendix B).

IV. Conclusion

The Commission should forbear from enacting rules on out-of-band and spurious emission limits on airborne and space-borne users of the 47 GHz band until such matters are addressed at WRC-00. Until such time, aeronautical and space-borne uses of the 47 GHz band should not be authorized. However, if the Commission decides to enact interference limits prior to international resolution, the limits must be significantly more stringent than those proposed in the NPRM, in order to protect radio astronomy observations in nearby bands from harmful interference.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

By: Bruce Alberts

Bruce Alberts
President

September 21, 1998

Attachments:
Appendix A: CORF Membership
Appendix B: Illustration of Potential Interference from High Altitude Platforms Operating in the 47.2 GHz and 47.9 GHz Bands to a Radio Astronomy Station Operating in the 42.5-43.5 GHz and 48.94-49.04 GHz Bands, communication from William Brundage, NRAO-VLA to Paul Steffes, Chair, CORF.

Direct correspondence to:

Paul J. Feldman, Esq.
Fletcher, Heald & Hildreth, PLC
1300 North 17th Street
11th Floor
Rosslyn, VA 22209
(703) 812-0400

With a copy to:

Dr. Robert L. Riemer
HA-562
National Research Council
2101 Constitution Ave., NW
Washington, DC 20418
(202)334-3520

NATIONAL RESEARCH COUNCIL

COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS

2101 Constitution Avenue Washington, D.C. 20418

BOARD ON
PHYSICS AND ASTRONOMY

(202) 334-3520
FAX: (202) 334-3575
INTERNET: BPA@NAS.EDU

COMMITTEE ON RADIO FREQUENCIES

Terms expire on June 30 of year indicated.

Paul Steffes, **Chair** 2001
School of Electrical and Computer Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0250
404-894-3128
Fax: 404-894-5935 or 4641
Email: ps11@prism.gatech.edu

David Brooks 1999
Department of Oceanography
Texas A&M University
College Station, TX 77843
409-845-5527
Email: dbrooks@ocean.tamu.edu

Darrel Emerson 1999
NRAO
Campus Building 65
949 N. Cherry Ave.
Tucson, AZ 85721
520-882-8250
Fax: 520-882-7955
Email: demerson@nrao.edu

Mark D. Jacobson 2001
Ocean Remote Sensing Division
NOAA/ETL
325 Broadway, A320
Boulder, CO 80303
303-497-6497
Fax: 303-497-3577
Email: mjacobson@etl.noaa.gov

Michael Klein 1999
Jet Propulsion Laboratory
303-402
4800 Oak Grove Dr.
Pasadena, CA 91109-8099
818-354-7132
Email: michael.j.klein@jpl.nasa.gov

Thomas Kuiper 2001
Jet Propulsion Laboratory
169-506
4800 Oak Grove Drive
Pasadena, CA 91109-8099
818-354-5623
Fax: 818-354-8895
Email: kuiper@jpl.nasa.gov

Mark McKinnon 2000
NRAO Green Bank
P.O. Box 2
Green Bank, WV 24944
304-456-2212
Email: mmckinno@nrao.edu

Ram M. Narayanan 2000
Dept. of Electrical Engineering
242N, WSEC
University of Nebraska-Lincoln
Lincoln, NE 68588-0511
402-472-5141
Fax: 402-472-4732
rnarayanan@unl.edu

NRC Staff

Donald C. Shapero, Director
Email: dshapero@nas.edu

Robert L. Riemer, Associate Director
Email: rriemer@nas.edu

Board on Physics and Astronomy
National Research Council
2101 Constitution Avenue
Washington, DC 20418
202-334-3520
Fax: 202-334-3575
Email: bpa@nas.edu

ILLUSTRATION OF POTENTIAL INTERFERENCE FROM HIGH ALTITUDE PLATFORMS OPERATING IN THE 47.2-47.5 GHz AND 47.9-48.2 GHz BANDS TO A RADIO ASTRONOMY STATION OPERATING IN THE 42.5-43.5 GHz AND 48.94-49.04 GHz BANDS

1. Introduction

The 1997 World Radiocommunication Conference (WRC-97), by footnote S5.552A, designated the 47.2-47.5 GHz and 47.9-48.2 GHz portions of the 47.2-50.2 GHz band for use by High Altitude Platform stations (HAPS) operating in the Fixed Service. The footnote does not specify directional indicators. Resolution 122 (WRC-97) called for technical studies to ascertain the requirements to protect the radio astronomy service (RAS) in adjacent bands (in particular the 42.5-43.5 GHz and 48.94-49.04 GHz bands) from spurious emissions of HAPS.

This document illustrates how spurious emissions from HAPS stations may impact radio astronomy observations. A realistic interference situation is considered, which consists of a HAPS at 25 km altitude, which is line-of-sight (LOS) to a RAS station located within the HAPS's rural area coverage (RAC) downlinks to user terminals, and near the HAPS's suburban area coverage (SAC) downlink to a gateway.

2. Characteristics of a High Altitude Platform

The assumed technical characteristics of the HAPS station are as follows (Doc 4-9S/16-E, "Technical Parameters for Typical Systems Using High Altitude Platforms", 17 February 1998):

Altitude above ground: 25 km (82,000 feet).

Coverage areas:

Urban (UAC): Elev:	-90 to -30 deg, Ground range 0-43 km.
Suburban (SAC): Elev:	-30 to -15 deg, Ground range 43-90 km.
Rural (RAC): Elev.:	-15 to -5 deg, Ground range 90-234 km.

Downlinks to user terminals within a RAC cell:

Transmitter Bandwidth/Channel: 33 MHz (TDMA-QPSK)

Transmitter Power/Channel: 2.2 dBW

Channels/Cell antenna (3000MHz/33MHz): 9

Transmitter Power/Cell (9*1.66W): 11.7 dBW

Cell Antenna gain (toward RAC cell at -15 to -5 degree elev.): 38 dBi

EIRP/Cell: 49.7 dBW

Downlinks to gateway stations within a SAC cell:

Transmitter Bandwidth/Cell: 264 MHz (64-QAM)

Transmitter Power/Cell: 11.7 dBW

Antenna gain (toward SAC cell at -30 to -15 degree elevation): 38 dBi

EIRP/Cell: 49.7 dBW

3. Illustration of HAPS signal levels at a RAS station

In the U.S.A. at least one potential operator has applied for authority to construct, deploy and operate a HAPS system. The scenario considered here is that of a HAPS, located over Albuquerque, New Mexico, 25 km above ground. The RAS station considered in this illustration is the U.S. National Radio Astronomy Observatory (NRAO) Very Large Array (VLA) interferometer west of Socorro, New Mexico. The VLA, which operates in both the 43 GHz and the 48 GHz RAS bands, consists of 27 antennas, each of 25-m diameter, arranged in a Y pattern up to 21 km in radius. Under the assumed HAPS location every one of the 27 antennas of the VLA would be line-of-sight (LOS) to the HAPS. In particular, the center of the VLA array could be located within a RAC cell, at 148 km from the HAPS.

	HAPS	VLA Center
Latitude N (deg):	35.106	34.249
Longitude W (deg):	106.629	107.618
Elevation (deg):	-8	8

Azimuth (deg): -141 38

Range (km): 148

Atmospheric attenuation at 48 GHz (from ITU-R Doc 7D/28 (3 May 1997)): 5.8 dB

Power Flux Density (PFD) at 1W EIRP toward VLA: -120.2 $dB(W/m^2)$.

3.1. HAPS in-band signal levels at the VLA RAS station

3.1.1 From downlinks to user terminals within the RAC cell

PFD at VLA site from HAPS maximum on-axis emissions of 49.7 dBW EIRP within a 300 MHz bandwidth:

$$(+49.7-120.2)= -70.5 \text{ dB}(W/m^2) \quad (1)$$

3.1.2 From downlinks to gateway stations within the SAC cell

Assuming the HAPS SAC gateway antenna beam is centered at -20 degree elevation and has a 2 degree beamwidth, the VLA at -8 degree elevation could be 34 dB down from the SAC antenna beam gain of 38 dBi.

PFD at VLA from HAPS emission of (49.7 dBW - 34dB) EIRP in a 264 MHz bandwidth:

$$(49.7 - 34-120.2 = -104.5 \text{ dB}(W/m^2) \quad (2)$$

3.2. Radio Regulation limits on HAPS spurious emissions and levels at the VLA

Article 131 of the NPRM addresses maximum permitted spurious emission power levels. The maximum permitted levels of spurious emissions are to be at least X dB below the total mean power P (Watts), where X = the lesser of 43 + 10log(P) or 80 dB for all emissions outside the licensee's authorized channel.

For the HAPS mean transmitter power of 11.7 dBW, X = 54.7 dB. Therefore the RR limit for HAPS spurious PFD at the VLA is 54.7 dB down from the HAPS in-band PFD.

From downlinks to user terminals within the RAC cell:

RR limit of spurious PFD (70.5 - 54.7) dB(W/m^2) = -125.2 dB(W/m^2) in a 1 MHz reference bandwidth, which corresponds to a SPFD of -185.2 dB(W/m^2/Hz) at the VLA.

From downlinks to gateway stations within the SAC cell:

RR limit of spurious PFD (-104.5 - 54.7) dB(W/m^2) = -159.2 dB(W/m^2) in a 1 MHz reference bandwidth, which corresponds to a SPFD of -219.2 dB(W/m^2/Hz) at the VLA.

4. Threshold levels of interference detrimental to radio astronomy observations

Recommendation ITU-R RA.769-1 gives protection criteria used for radio astronomy measurements in terms of frequency band, receiver noise and bandwidth parameters, integration time, continuum or spectral line observations, radioastronomy antenna side-lobe gain toward the source of the interfering signal, and spectral power flux density of the interfering signal incident on the radioastronomy antenna. The integration time used in this calculation is 2000 seconds, as per ITU-R Recommendation RA.769-1. (Actual integration times may be longer, increasing the amount of interference to the radio telescope.) The antenna side-lobe gain toward a HAPS applicable to this illustration is 0 dBi because the recommendation assumes the model for large parabolic antennas given by Recommendation ITU-R SA.509. In this model, the side-lobe level decreases with angular distance θ (degrees) from the main beam axis, and is equal to $32-25\log\theta$ (dBi) for $1\text{deg}<\theta<48\text{deg}$. A level of > 0 dBi occurs at 19 degrees from the main beam axis. The 38 degree cone of the side-lobe gain <0 dBi includes 5.5% of the visible hemisphere. The VLA may be used in several configurations. In the most compact configuration, its sensitivity to interference approaches that of a single dish telescope, especially for baselines connecting antenna pairs which project close to the source of interference.

For these parameters, from Table 1 and footnote (2) of Recommendation ITU-R RA.769-1, the threshold level of detrimental interference to VLA continuum observations in the 42.5-43.5 GHz band is an aggregate power flux-density of -137 dB(W/m^2) in a 1 GHz bandwidth. The equivalent SPFD is -227 dB(W/m^2/Hz). From Table 2 and footnote (1) of Recommendation ITU-R RA.769-1, the threshold level of detrimental interference to VLA spectral line observations in the 42.77-42.87, 43.07-43.17, and 43.37-43.47 GHz bands is a PFD of -153 dB(W/m^2) in a reference bandwidth of 500 kHz. In this case, the equivalent SPFD is -210 dB(W/m^2/Hz). Also, the threshold level of detrimental interference in the 48.94-49.04 GHz band is -152 dB(W/m^2) in a reference bandwidth of 500 kHz which corresponds to a SPFD of -209 dB(W/m^2/Hz).

Recommendation ITU-R RA.1237, "Protection of the Radio Astronomy Service from

Unwanted Emissions Resulting from Applications of Wideband Digital Modulation," Recommendation ITU-R RA.517.2, "Protection of the Radioastronomy Service from Transmitters in Adjacent Bands," and Recommendation ITU-R RA.611-2, "Protection of the Radioastronomy Service from Spurious Emissions" provide additional information on the protection of the radio astronomy service.

5. Illustration of potential interference by HAPS in the RAS band 48.94-49.04 GHz

The 48.94-49.04 GHz band is allocated by footnote S5.555 to the RAS on a primary shared basis with the fixed, fixed-satellite (E-s) and mobile services. Footnote S5.149 urges administrations to take all practicable steps to protect RAS spectral line observing from harmful interference in this band. It also states that emissions from spaceborne or airborne stations are particularly serious sources of interference to RAS.

In the illustrative situation of this example, the ratios of HAPS RR limit of spurious SPFD at the VLA station to the detrimental interference level are:

From downlinks to user terminals within the RAC cell:

$$-185.2 \text{ dB(W/m}^2\text{/Hz)} - (-209 \text{ dB(W/m}^2\text{/Hz)}) = +23.8 \text{ dB.}$$

From downlinks to gateway stations within the SAC cell:

$$-219.2 \text{ dB(W/m}^2\text{/Hz)} - (-209 \text{ dB(W/m}^2\text{/Hz)}) = -10.2 \text{ dB.}$$

Thus, the discrepancy between the spurious emissions applicable to HAPS transmitters and the threshold detrimental SPFD levels in this RAS band at the VLA as given by Recommendation ITU-R RA.769-1, is nearly 24 dB for the HAPS RAC user transmitter. This RAS band is separated by 740 MHz from the 48.2 GHz band edge of the HAPS transmitter.

6. Illustration of potential interference by HAPS in the RAS band 42.5-43.5 GHz

The RAS shares a primary allocation in the 42.5-43.5 GHz band with the Fixed, Fixed-satellite (E-s) and Mobile (except aeronautical mobile) services. ITU-R footnote S5.149 urges administrations to take all practicable steps to protect RAS continuum and spectral line observations from harmful interference in this band. It also states that emissions from spaceborne or airborne stations are particularly serious sources of interference to RAS.

6.1. Spectral line observing in the sub-bands 42.77-42.87 GHz, 43.07-43.17 GHz and 43.37-43.47 GHz

In this example, the ratios of HAPS RR limit of spurious SPFD at the VLA to the detrimental interference level at the VLA are:

From downlinks to user terminals within the RAC cell:

$$-185.2 \text{ dB(W/m}^2\text{/Hz)} - (-209 \text{ dB(W/m}^2\text{/Hz))} = +24.8 \text{ dB.}$$

From downlinks to gateway stations within the SAC cell:

$$-219.2 \text{ dB(W/m}^2\text{/Hz)} - (-209 \text{ dB(W/m}^2\text{/Hz))} = -9.2 \text{ dB.}$$

Thus, the discrepancy between the spurious emissions applicable to HAPS transmitters and the threshold detrimental SPFD levels in this RAS band at the VLA as given by Recommendation ITU-R RA.769-1, is nearly 25 dB for the HAPS RAC transmitter. It is noted that these RAS sub-bands are separated by 3.73 GHz from the 47.2 GHz band edge of the HAPS transmitter.

6.2. Continuum observing in the 42.5-43.5 GHz band

In this example, the ratios of HAPS RR limits of spurious SPFD to the detrimental interference level at the VLA are:

From downlinks to user terminals within the RAC cell:

$$-185.2 \text{ dB(W/m}^2\text{/Hz)} - (-227 \text{ dB(W/m}^2\text{/Hz))} = +41.8 \text{ dB.}$$

From downlinks to gateway stations within the SAC cell:

$$-219.2 \text{ dB(W/m}^2\text{/Hz)} - (-233.3 \text{ dB(W/m}^2\text{/Hz))} = +14.1 \text{ dB.}$$

Thus, the discrepancy between the spurious emissions applicable to HAPS transmitters in the subject NPRM and the threshold detrimental SPFD levels in this RAS band at the VLA as given by Recommendation ITU-R RA.769-1, are nearly 42 dB for the HAPS RAC transmitter and 8 dB for the SAC transmitter. It is noted that this RAS band is separated by 3.7 GHz from the 47.2 GHz band edge of the HAPS transmitter.

7. Conclusions

The illustrative interference situation described here shows a significant discrepancy between the detrimental interference levels to the RAS observations in the 42.5-43.5 GHz and the 48.94-49.04 GHz bands as given in Recommendation ITU-R RA.769-1 and the spurious emission levels permitted under the subject NPRM. For HAPS downlinks to user terminals in a RAC cell, the levels proposed are between 24 dB and 42 dB in excess of the detrimental interference levels. Clearly, special consideration of transmitter spurious emissions will be required of HAPS systems for the protection of radio astronomy observations in these bands.